16. Methods of breeding – introduction and acclimatization

The following are the methods of breeding autogamous plants.

1. Introduction
2. Selection
    a) Pure line selection
    b) Mass selection
3. Hybridization and selection
        i) Inter varietal
            a) Pedigree Method
            b) Bulk Method.
            c) Single Seed Descent Method.
            d) Modified Bulk Method
            e) Mass - Pedigree Method.
        ii) Interspecific hybridization
4. Back cross method
5. Multiline varieties
6. Population approach
7. Hybrids.
8. Mutation breeding
9. Polyploidy breeding
10. Innovative techniques

I. Plant introduction

Definition

Taking a genotype or a group of genotypes in to a new place or environment where they were not grown previously. Thus introduction may involve new varieties of a crop already grown in that area, a wild relative of the crop species or totally a new crop species for that area.

E.g. a) Introduction of lRRl rice varieties..

b) Introduction of sunflower wild species *from* Russia

c) Introduction of oilpalm in to Tamil Nadu.

Plant introduction may be of two types. 1. Primary Introduction and 2. Secondary Introduction

1. **Primary Introduction**

When the introduced crop or variety is well suited to the new environment, it is directly grown or cultivated with out any alteration in the original genotype. This is known as primary introduction. E.g. IR. 8, IR 20, IR 34, IR 50 rice varieties; oil palm varieties introduced *from* Malaysia and Mashuri rice *from* Malaysia.

2. **Secondary Introduction**

The introduced variety may be subjected to selection to isolate a superior variety or it may be used in hybridization programme to transfer some useful traits. This is known as secondary Introduction.E.g. In soybean EC 39821 introduced from Taiwan is subjected to selection and variety Co 1 was developed. In rice ASD 4 is crossed with IR 20 to get Co 44 which is suited *for* late planting.

Objectives of Plant Introduction

- To introduce new plant species there by creating ways to build up new industries.E.g. Oil palm
- To introduce high yielding varieties to increase food production. E.g. Rice and wheat.
- To enrich the germplasm collection. E.g. Sorghum, Groundnut.
- To get new sources of resistance against both biotic and abiotic stresses.

E.g. NCAC accessions to have rust resistance in groundnut. Dasal rice variety for saline resistance.Aesthetic value – ornamentals are introduced for aesthetic value.

Plant Introduction Agencies

Most of the introductions occurred very early in the history. In earlier days the agencies were invaders travelers, traders, explorers, pilgrims and naturalists Muslim invaders introduced in India cherries and grapes. Portuguese introduced maize, ground nut, chillies, potato, sweet potato, guava, pine apple, papaya and cashew nut. East India Company brought tea. Later Botanic gardens played a major role in plant Introduction

A centralized plant introduction agency was initiated in 1946 at IARI, New Delhi. During 1976 National Bureau of Plant Genetic Resources (NBPGR) was started. The bureau is responsible for introduction and maintenance of germplasm of agricultural and horticultural plants. Similarly Forest Research Institute, Dehradun has a plant introduction organization, which looks after introduction, maintenance and testing of germplasm of forest trees. Besides

NBPGR the Central Research Institutes of various crops also maintain working germplasm. All the introductions in India must be routed through NBPGR, New Delhi. The bureau functions as the central agency for export and introduction of germplasm.

At International level International Board of Plant Genetic Resources (IBPGR) with head quarters at Rome, Italy is responsible for plant introduction between countries.

Procedure for plant Introduction

The scientist / University will submit the requirement to NBPGR. If the introduction is to be from other countries, NBPGR will address IBPGR for effecting supply. The IBPGR will assign collect the material from the source and quarantine them, pack them issue phytosanitary certificate suitably based on the material and send it to NBPGR. The NBPGR will assign number for the material, keep part of the seed for germplasm and send the rest to the scientist.

There are certain restrictions in plant introduction. Nendran banana from Tamil Nadu should be not be sent out of state because of bunchy top disease. Similarly we cannot import Cocoa from Africa, Ceylon, West Indies, Sugarcane from Australia, Sunflower from Argentina.

Functions of NBPGR

1. Introduction maintenance and distribution of germplasm
2. Provide information about the germplasm through regular publications.
3. Conduct training courses to the scientist with regard to introduction and maintenance of germplasm.
4. Conduct exploratory surveys for the collection of germplasm.
5. To set up Natural gene sanctuaries.

Merits of plant introduction.

1. It provides new crop varieties, which are high yielding and can be used directly
2. It provides new plant species.
3. Provides parent materials for genetic improvement of economic crops.
4. Enriching the existing germplasm and increasing the variability.
5. Introduction may protect certain plant species in to newer area will save them from diseases. E.g. Coffee and Rubber.

Demerits

1. Introduction of new weed unknowingly.E.g. *Argemone mexicana, Eichornia and* Parthenium

2. Introduction of new diseases: Late blight of potato from Europe and Bunchy top of banana from Sri Lanka

3. New pests: Potato tuber moth came from Italy

4. Ornamentals becoming weeds: Lantana camara

5. Introduction may cause ecological imbalance E.g.Eucalyptus.

Acclimatization

When superior cultivars from neighbouring or distant regions are introduced in a new area, they generally fail initially to produce a phenotypic expression similar to that in their place of origin. But later on they pickup and give optimal phenotypic performance, in other words they become acclimatized to the new ecological sphere. Thus acclimatization is the ability of crop variety to become adapted to new climatic and edaphic conditions.

The process of acclimatization follows an increase in the frequency of those genotypes that are better adapted to the new environment.

The success of acclimatization depends upon two factors

i) Place effect

ii) Selection of new genotypes.

Selection, Mass selection, pure line selection and Johannson's pure line theory, genetic basis.

Selection in Self-Pollinated Crops

To get successful results by selection there are two pre-requisites.

a) Variation must be present in the population.

b) The variation must be heritable.

History of selection

Selection was practiced by farmers from ancient times. During 16^{th} century Van Mons in Belgium, Andrew knight in England and Cooper in USA practiced selection in crop plants and released many varieties.

Le coutier, a farmer of island of New Jersey published his results on selection in wheat in the year 1843. He concluded that progenies from single plants were more uniform. During the same period Patrick Shireff, a scotsman practiced selection in wheat and oats and developed some valuable varieties.During 1857 Hallet in England practiced single plant selection in wheat,

oats and barley and developed several commercial varieties.

About this time **Vilmorin** proposed individual plant selection based on progeny testing. This method successfully improved the sugar content in sugar beet. His method was called as vilmorin isolation principle. He emphasized that the real value of a plant can be known only by studying the progeny produced by it. This method was successful in sugar beet but not in wheat. This shows the in-effectiveness of selection in cross pollinated crops. Today progeny test is the basic step in every breeding method.

Pureline theory

A pure line is the progeny of a single self fertilized homozygous plant. The concept of pureline was proposed by **Johannsen** on the basis of his studies with beans *(Phaseolus vulgaris)* variety called Princess. He obtained the seeds from the market and observed that the lot consisted of a mixture of larger as well as smaller size seeds.

Thus there was variation in seed size. Johannsen selected seeds of different sizes and grown them individually.

Progenies of larger seeds produced larger seeds and progenies from smaller seeds produced small seeds only. This clearly showed that there is variation in seed size in the commercial lot and it has a genetic basis. He studied nineteen lines al together. He concluded that the market lot of the beans is a mixture of purelines.

He also concluded whatever variation observed with in a pureline is due to environment only. Confirmatory evidence was obtained in three ways. In line 13 which is having 450 mg seed wt he divided the seeds on weight basis. He divided the line into seeds having 200, 300, 400 and 500 mg weights and studied the progenies. Ultimately he got lines having weight ranging from 458 to 475. Thus the variation observed is purely due to environment.

The second evidence was that selection with in a pureline is ineffective. From a pureline having 840 mg selection was made for large as well as small seeds. After six generations of selection the line for large seed as well as for small seed gave progenies having 680-690 mg. Thus it was proved that selection within a pureline is ineffective.

In third evidence when parent - offspring regression was worked in line thirteen. It worked to zero indicating that variation observed is non heritable and it is due to environment only.

Origin of variation in pure lines

1. Mechanical mixtures.
2. Natural hybridization.
3. Chromosomal aberrations.
4. Natural mutation or spontaneous mutation.
5. Environmental factors.

Effect of self-pollination on genotype

Self-pollination increases homozygosity with a corresponding decrease in heterozygosity. For example an individual heterozygous for a single gene Aa is self pollinated in successive generations, every generation of selfing will reduce the frequency of heterozygote Aa to 50 percent of that in the previous generation. There is a corresponding increase in homozygotes AA and aa. As a result, after 10 generations of selfing virtually all the plant in the population will be homozygous AA and aa.

No. of generations of selfing	Frequency (%)			Frequency (%)	
	AA	Aa	aa	Homozygote	Heterozygote
0	0	100	0	0	100
1	25	50	25	50	50
2	25 + 12.5	25	25 + 12.5	75	25

This can be calculated by the formulae

$[2^m - 1) / 2^m]^n$ where m = No. of generations of self-pollination and

n = No. of genes segregating.

When number of genes are segregating together, each gene would become homozygous at the same rate as Aa. Thus the number of genes segregating does not affect the percentage of homozygosity. Similarly linkage between genes does not affect the percentage of homozygosity in the population.

Genetic advance under selection

Normally selection is practiced based on the phenotype of the individual plant. The phenotype in turn is the result of joint action of genotype and environment i.e.,

$V_P = Vg + V_E$ Where P= phenotype; G = genotype; E = Environment

The genetic advance is calculated by the following formula.

Genetic advance (GS) = (K) (H) (SD P) or $GS = (K) (VP)^{½} (Vg / Vp)$,

Where GS is the genetic advance under selection, K is the selection differential, SD P is the phenotypic standard deviation of base population and H is the heritability of the character under selection. The estimates of GS have the same unit as that of the mean.

Pureline Selection

A large number of plants are selected from a self pollinated crop. The selected plants are harvested individually. The selected individual plants are grown in individual rows and evaluated and best progeny is selected, yield tested and released as a variety.

Characteristics of purelines

1. All plants within a pure line have the same genotype.
2. The variation with in a pureline is environmental and nonheritable.
3. Purelines become genetically variable with time due to natural hybridization, mutation and mechanical mixtures.

General steps for making a pureline selection

First Season: From the base population select best looking plants having the desirable characters. Harvest them on single plant basis.

Second Season: The selected single plants are grown in progeny rows and estimate the performance. Reject unwanted progenies.

Third Season: Repeat the process of second season.

Fourth Season: Grow the selected single plants in replicated preliminary yield trial along with suitable check or controI variety.

Fifth Season: Conduct regular comparative yield trial along with check variety and select the best culture.

Sixth Season: Conduct multilocation trial in different research stations along with local check.

Seventh Season: Conduct Adaptive Research Trial in farmer's field. Fix the best yielder and release it as a variety thro' Variety Release committee.

Advantage of pureline selection.

1. Achieves maximum possible improvement over the original variety.
2. Extremely uniform in appearance.
3. Because of the uniformity, a variety is easily identified and seed certification is easy.

Disadvantages

1. It does not have wide adaptability because improvement is made only in the local variety.
2. Time required for developing a variety is more when compared to mass selection.
3. Depending on the genetic variability present in the base population only the improvement is made. If there is no genetic variability improvement cannot be made.
4. Breeder has to spend more time compared to mass selection.

Mass Selection

Here a large number of plants having similar phenotype are selected and their seeds are mixed together to constitute a new variety. Thus the population obtained-from selected plants will be more uniform than the original population. However they are genotypically different.

Steps

First season

From the base population select phenotypically similar plants, which may be 200 2000. Harvest the selected plants as a bulk.

Second season

The bulk seed is divided into smaller lots and grown in preliminary yield trial along with control variety. Dissimilar phenotypes are rejected. Higher yielding plots are selected.

Third to Sixth Season

With the selected lots conduct yield trials along with appropriate check or control. Select the best one and release it as a variety.

Merits of Mass Selection

1. Varieties developed will be having more adaptability since each plant is genotypicaly not similar. They have buffering action against abnormal environment.
2. Time taken for release of a variety is less.
3. The genetic variability present in the original population is maintained.

Demerits

1. Compared to pure line variety they may not be uniform.

2. In the absence of progeny test we are not sure whether the superiority of selected plant is due to environment or genotype.

3. May not be as uniform as that of a pureline variety and certification is difficult.

Comparison between pure line and mass selections

	Pureline selection	**Mass selection**
1.	The new variety is a pureline	The new variety is a mixture of purelines.
2.	The new variety is highly uniform. In fact, the variation within a pureline variety is purely environmental.	The variety has genetic variation of quantitative characters, although it is relatively uniform in general appearance
3.	The selected plants are subjected to progeny test	Progeny test is generally not carried out
4.	The variety is generally the best pureline present in the original population. The pure line selection brings about the greatest improvement over the original variety	The variety is inferior to the best pureline because most of the purelines included in it will be inferior to the best pure line
5.	Generally, a pure line variety is expected to have narrower adaptation and lower stability in performance than a mixture of pure lines	Usually the variety has a wider adaptation and greater stability than a pureline variety
6.	The plants are selected for the desirability. It is not necessary they should have a similar phenotype	The selected plants have to be similar in phenotype since their seeds are mixed to make up the new variety.
7.	It is more demanding because careful progeny tests and yield trials have to be conducted.	If a large number of plants are selected, expensive yield trials are not necessary. Thus it is less demanding on the breeder.

17. Hybridization – Aims, objectives and types of hybridization

Objective of hybridization

The chief objective of hybridization is to create variation. When two genotypically different plants are crossed, the genes from both the parents are brought together in F_1. Segregation and recombination produce many new gene combinations in F_2 and subsequent generations.

The degree of variation produced depends on the number of heterozygous genes in F_1. The number of heterozygous genes in F_1 in turn depends on number of genes for which the two parents differ. If the parents are not related they may differ for several genes.

Combination breeding

The main aim of combination breeding is the transfer of one or more characters into a single variety from other varieties. These characters may be governed by oligogenes or polygenes. In this approach, increase in yield is obtained by correcting the weaknesses in the yield contributing traits like tiller number, grains per panicle, seed weight of the concerned variety. Example for combination breeding is disease resistance achieved by backcross breeding. Pedigree method is also another example.

Transgressive breeding

Transgressive segregation is the production of plants in F_2 generation that are superior to both the parents for one or more characters. Such plants are produced by the accumulation of favourable genes from both the parents as a consequence of recombination. In this case the parents involved in hybridization must combine well with each other and preferably be genetically diverse. This way, each parent expected to contribute different plus genes which when brought together by recombination gives rise to transgresive segregation. The pedigree method as well as population approach are designed to produce transgresive segregants.

Procedure of hybridization

1. Set up your objective.
2. Selection of parents.
3. Evaluation of parents.
4. Sowing plan.

s. Emasculation and dusting.

6. Labelling and bagging.

7. Harvesting and storage of seeds.

1. Objective

Based on the requirement, set your objective. Because based on the objective only the selection of parents is done. If it is resistance breeding one of the parents must be a donor.

2. Selection of parents

Normal practice is, the female parent will be a locally adapted one in which we can bring in the plus genes. In case of intervarietal hybridization geographically diverse parents will be selected so as to get superior segregants.

3. Evaluation of parents

In case of parents which are new to the region they must be evaluated for their adaptability. Further to ensure homozygosity, they must be evaluated.

4. Sowing plan

If the flowering duration is same, simultaneous sowing of both the parents can be done. Otherwise staggered sowing is to be followed. The normal practice is to raise the ovule parent in the centre of the plot in rows and on the border pollen parent for each combination.

5. Emasculation and dusting

Emasculation is the removal of immature anthers from a bisexual flower. Depending on the crop the emasculation practice differs. Normal practice of hand emasculation and dusting of pollen is done. Depending on the time of anthesis the time of emasculation differs. For E.g. in rice the anthesis at Coimbatore takes place between 7.00 to 10.00 A.M. So the emasculation is done at around 6.30 A.M. and dusting of pollen is done immediately.

6. Labelling and bagging

Immediately after hybridization put a label indicating the parents and date of crossing. Put appropriate cover to prevent foreign pollen, contamination.

7. Harvesting and storage of seeds

Normally 15-20 days after crossing the seeds will be set. In the case of pulses the crossed pods can be easily identified by the shrunken nature of pod and seed set will be reduced. Harvest of crossed seeds must be done on individual plant basis. Seeds collected from individual plants are to be stored in appropriate containers with proper label and stored.

Distant Hybridization

When crosses are made between two different species or between two different

genera, they are generally termed as **distant hybridization (or) wide hybridization**

History

Thomas Fairchild 1717 was the first man to do distant hybridization. He produced an hybrid between two species of *Dianthus*

*Dianthus caryophyllus (*Carnation) x *D. barbatus (*Sweet william)

Inter generic hybrid produced by Karpechenko, a Russian Scientist in 1928. *Raphano brassica* is the amphidiploid from a cross between Radish *(Raphanus sativus)* and cabbage *(Brassica oleraceae).* Triticale was produced by Rimpau in 1890 itself. Triticale is an amphidiploid obtained from cross between wheat and rye. Another example is *Saccharum* nobilisation involving three species.

Hybrids in self-pollinated crops - problems and prospects

Exploitation of heterosis through F I hybrids has hitherto been the prerogative of cross- pollinated crops, chiefly due to their breeding systems favouring allogamy. However, possibilities of working for such a proposition have recently been realized in self-pollinated corps also. Indeed, exploitation of hybrid vigour in autogamous crops is easy and less time-consuming in that homozygous inbreds are already available. There is practically no difference with regard to hybrid breeding between self and cross-pollinated crops. But the prospects of hybrids in seIfers is dependant on three major considerations.

1. How high a heterotic effect can be gained under optimal production conditions.
2. In fact, a breeder's main concern is the magnitude rather than the frequency of occurrence of heterosis in crops. Thus the consideration is whether or not it is possible to obtain economically viable heterosis.
3. How much of the yield surplus due to high heterosis can offset the extra seed cost? In major self-pollinated crops like wheat, barley, rice, etc., the seed rate per unit area is exorbitant and hence the hybrid seed requirement is also more.
4. How efficient and effective is the mechanism of cross-pollination in seIfers? By nature, self-pollinated crops are shy pollinators with very poor pollen maneuverability (or movability to effect allogamy). Therefore, the efficiency (degree of allogamy) with which cross pollination can take place on a commercial scale is the true determinant of the success of a hybrid programme in seIfers.
5. Among self-pollinated crops, FI hybrids have been graduated into the farmer's field in

barely, tomato, Sorghum (often-cross-pollinated) and wheat. Briggle (1963) presented a vivid account of heterosis in wheat. Work in rice is also most encouraging (IRRI, 1972).

Methods of handling of segregating generations – pedigree method, bulk method, back cross method and various modified methods

Pedigree method

In this method, individual plants are selected from F_2 and subsequent generations and their progenies are tested. During this process details about the plants selected in each generation is recorded in Pedigree Record. By looking into Pedigree record we can know about the ancestry of the selected plants.

For maintenance of pedigree record the basic thing required is Crossing Ledger. This Ledger gives the details about parentage, Season in which the cross is made.

Sl.No.	Cross Number	Parentage
1.	XS 9801	Co2 x MS *9804*
2.	X S 9802	. Co4 x C152
3.	X S 9803	Co 1 x Co4

There are several ways to maintain the pedigree Record. The selection of plants starts from F_2 onwards. The details about selected plants can be recorded as follows. E.g. F_2 X S *9801* - 7. Here the 7 denotes seventh plant selected.

In F_3 if selection is made from the 7th plant of cross X S 9801 it can be recorded as F_3 X S 9801 - 7 - 4. The number four indicates that fourth plant of 7th plant of F_2 is selected. This can be followed till F_4 or F_5 generations. After F_4 or F_5 the selected plants are bulked to form a family.

In the pedigree record all the biometerical data like plant height, number of branches, No. of pods / plant, pod length, seeds / pod, pod weight, seed weight are recorded.

Merits of Pedigree Method

1. Gives maximum opportunity to the breeder to use his skill and judgement for the selection of plants.
2. Well-suited for characters which are simply inherited
3. Transgressive segregants can be easily identified thro' records.

4. Information about inheritance is precisely obtained.

Demerits

1. Maintenance of pedigree record is time consuming and limits handling of larger population.
2. The success in this method is largely dependent on skill of the breeder. There is no opportunity for natural selection.
3. Selection for yield in F_2 and F_3 is ineffective. If care is not taken to maintain larger population, valuable materials may be lost.

Pedigree Method Procedure

F_1 Generation

The F_1 seeds are space planted so that full expression of F_1 can be had. It is advisable to raise the parents involved in the cross to raise as border rows so that dominance and other characters can be studied. The F_1s are harvested as single plants.

F_2 generation

In F_2, 2000 to 10,000 plants per cross are planted. About 100 - 500 plants are selected and harvested on single plant basis. The selection in F 2 depends upon the skill of the breeder. The selection intensity may be 5 to 10%.

F_3 generation

Individual plant progenies are space planted. Again desirable plants are selected. From F_3 onwards the term family is introduced. The line selected from each cross is termed as family.

F_4 generation

Similar to F_3.

F_5 generation

Many families would have attained homozygosity and may be harvested as row bulk.

F_6 generation

The row bulk may be assessed in multi row trial. The families exhibiting segregation may be isolated and studied separately.

F_7 generation

RRYT

F_8 generation

PYT

CYT 3 seasons.

Basis of selection

Depending upon the objective, selection is to be made in segregating generation. For insect and disease resistance part of the seeds may be reserved in segregating generation and the rest may be subjected to epiphytotic conditions. The families exhibiting resistance may be identified and the reserve seeds may be used for further selection and testing.

Early generation testing

If superior families are identified in F_3 or F_4, they can be tested for desirable characters and this is known as early generation testing.

Shuttle breeding

This is followed especially in disease or insect resistance breeding. For e.g. at Coimbatore YMV in blackgram is in epidemic form during summer season only. Whereas at Vamban (Pudukkottai) the YMV is epidemic during kharif season. So instead of waiting for next summer at Coimbatore the materials can be tested at Vamban during kharif and thus one season is saved.

Off season nursery

Some crops may be season bound. But it may be non - season bound in certain agro - climatic zone. For e.g. *Thalai virichan cholam. (Sroxburghii)* is season bound at Coimbatore. It has to be sown during July - August and harvested during December January. But this *Sroxbughii* is non - season bound in Yercaud. So to save one season, the segregating material can be raised during Rabi summer at Yercaud. This method is otherwise known as rapid generation advancement (RGA).

Bulk Method

In this method F_2 and subsequent generations are harvested as bulk to grow the next generation. The duration of bulking may be 6 - 7 generations. Selection can be made in each generation but harvest is done as bulk. This is similar to mass selection. At the end of bulking period single plant selection is made and tested for yielding ability. If bulking period is long say 20 - 30 seasons, then natural selection acts on the homozygous lines. In this method the breeder uses his skill for selecting the plants and at the same time there is no pedigree record. This saves much time and labour.

Merits of bulk method

1. Simple, convenient and inexpensive
2. By inducing artificial epiphytotic conditions undesirable or weaker genotypes can be eliminated.
3. If bulking period is longer natural selection operates and desirable genotypes are selected.
4. No pedigree record is maintained.
5. Since large population is grown there is chance for appearance of transgressive segregants which will be superior than parents or F_2

Demerits

1. Takes much longer time to develop a new variety.
2. In short term bulk there is no chance for natural selection.
3. A large number of progenies are to be selected in each generation which requires much labour, time and space.
4. We cannot get information on inheritance.

Single Seed - Descent Method

It is the modification of the bulk method. In this method a single seed from each of the F_2 plants is collected and bulked to raise F_3 generation. Similarly single seed from each F_3 plant is collected and carried forward to F_4. This procedure is followed till F_6 or F_7. After wards single plant selection is made and studied in progeny rows.

In this Scheme the main features are:

1. Lack of selection till F_6 or F_7 when the population becomes homozygous.
2. Each F2 plant is represented till F_6 or F_7 generation.
3. In this method there are chances for reduction in population size due to pest, disease or poor germination.
4. Rapid generation advancement (RGA) can be made with the use of glass house or off season nursery.

Modified bulk method

Here selection can be practiced in F_2 and F_3 and subsequent generations. There will not be any pedigree record but superior plants are selected bulked and carried forward. In F_4 superior plants are selected and harvested on single plant basis. In F5 these single plants are studied in progeny rows and best progenies are selected and harvested. In F_6 PYT can be conducted to select best families. In subsequent generations regular trials can be conducted.

This modification of the bulk method provides an opportunity for the breeder to exercise his skill and judgement in selection. Further there is no maintenance of pedigree record which is another advantage.

Mass pedigree method

This was proposed by Harrington. It is a solution to one of the deficiencies in the pedigree method of breeding. For e.g. if the population is to be subjected to disease resistance screening like YMV and if there is no method to create artificial epiphytotic conditions, it is wasteful to study the population in pedigree method. Instead we can carry the population as a mass and test them when there is occurrence of the disease. When conditions are favourable for the disease, we can terminate the bulking and resort to single plant selection.

Comparison between Pedigree and Bulk Methods

S. No.	**Pedigree method**	**Bulk method**
1.	Individual plants are selected in F_2 and the subsequent generations and individual plant progenies are grown.	F_2 and the subsequent generations are maintained as bulks.
2.	Artificial selection, artificial disease epidemics etc., are an integral part of the method	Artificial selection, artificial disease epiphytotics etc., may be used to assist natural selection. In certain cases, artificial selection may be essential
3.	Natural selection does not play any role in the method.	Natural selection determines the composition of the populations at the end of the bulking period.
4.	Pedigree records have to be maintained which is often time consuming and laborious	No pedigree record is maintained.
5.	It generally takes 14-15 years to develop a new variety and to release it for cultivation.	It takes much longer for the development and release of a variety. The bulk population has to be

		maintained for more than 10 years for natural selection to act.
6.	Most widely used breeding method.	Used only to a limited extent.
7.	It demands close attention from the breeder from F_2 onwards as individual plant selections have to be made and pedigree records have to be maintained.	It is simple, convenient and inexpensive and does not require much attention from the breeder during the period of bulking
8.	The segregating generations are space - planted to permit individual plant selection.	The bulk populations are generally planted at commercial planting rates.
9.	The size of population is usually smaller than that in the case of bulk method.	Large populations are grown. This and natural selection are expected to increase the chances of the recovery of transgressive segregants.

25. Hybridization

Clonal crops are generally improved by crossing two or more desirable clones, followed by by selection in the F1 progeny and in the subsequent clonal generations. Once the F1 has been produced, the breeding procedure is essentially the same as clonal selection. The improvement through hybridization involves the following three steps:

1. Selection of parents,
2. Production of F1 progeny, and
3. Selection of superior cones.

Hybridization can be used only in such crops, which can reproduce sexually. In case of those crops where sexual reproduction is lacking, mutagenesis or biotechnological approaches can be applied.

Selection of Parents

Selection of the parents to be used in hybridization is very important since the value of F1 progeny would depend upon the parents used for producing the F1. Parents are generally selected on the basis of their known performance both as varieties and as parents in hybridization programmes. The performance of a strain in hybridization programmes depends on its prepotency and general combining ability. It would be highly desirable to know the relative values of CGA and SCA in the crop to be improved. If GCA is more important, a small number of parents with good should be used in hybridization programmes. On the other hand, when SCA is more important, a large number of parents should be used to produce a large number of F1 families In an effort to find some outstanding crosses.

A recent suggestion is to partially inbreed the parents to be used in hybridization programmes. Clonal crops show severe inbreeding depression, but it is expected that one generation of selfing or 2-3 generations of sib-mating may not reduce vigour and fertility too severely. Inbreeding may enable the breeder to identify plants that would have a greater concentration of desirable alleles. These plants may be more prepotent as parents than the highly heterozygous clones. The practice is gaining some favour with plant breeders.

Production of F1 progeny

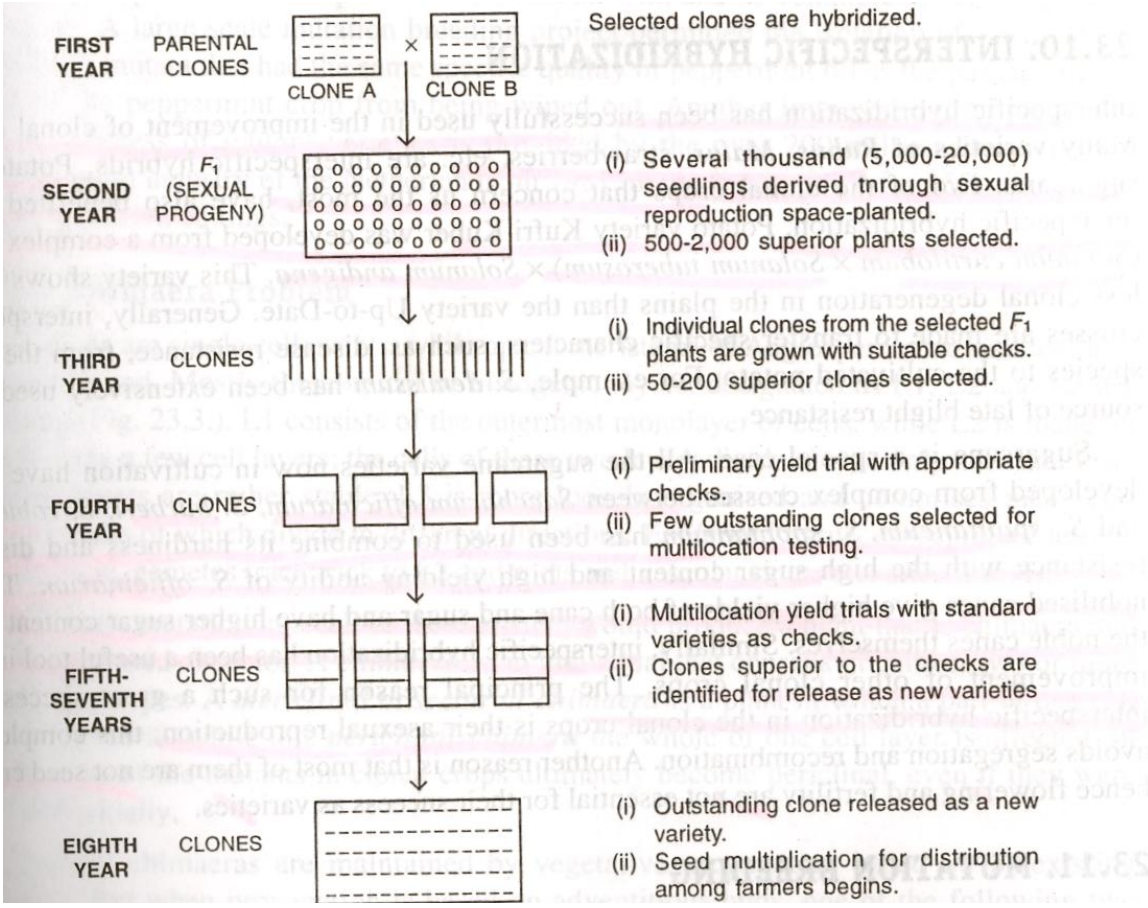
Generally, clonal crops are cross-pollinated and they may show self-incompatibility. The selected parents may be used to produce single crosses involving two parents or an equivalent of a polycross involving more than two parents.

Selection among FI Families

When the breeding value of parents is not known, and the relative contributions of GCA and SCA is not available, a large number of crosses have to be made in order to ensure that at least some of the crosses would produce outstanding progeny in F,. This is particularly true in a species where crop improvement has not been done or has been done at a small scale. In such cases, it would be cumbersome to evaluate a large number of F, progeny is detail. To avoid this, generally small samples of several F, populations are grown. The general worth of individual F, populations is estimated visually. The presence of outstanding individuals in the F, populations is also noted, and inferior F1's are eliminated. Promising F1's with outstanding individuals are then grown at a much larger scale for selection. The procedure is designed to save time, space and labor by planting only small populations of a large number of crosses at the preliminary stage.

Selection within FI Families

The selection procedure within F_J populations is essentially the same as that in the case of clonal selection. The various steps involved in the breeding of clonal crops through hybridization are briefly described below. From second year onward, these should be read along with the steps described in clonal selection.



First Year

Clones to be used as parents are grown and crosses are made to produce F_1 progeny.

Second Year

Sexual progeny from the cross, i.e., seedlings obtained from seeds, are grown. Undesirable plants are eliminated. Few hundred t9 few thousand desirable plants are selected.

Third Year

Clones from the selected individual plants are grown separately. Poor and inferior clones are eliminated. Up to 200 superior clones may be selected for preliminary yield trial.

Fourth Year

A replicated preliminary yield trial is conducted in which suitable checks are included for comparison. Few outstanding clones are selected for trials at several locations.

Fifth to seventh year

Replicated yield trials are conducted at several locations. Suitable checks are included for comparison. One or a few outstanding clones are identified and realsed as new varities.

Eighth year

The clones released as varities are multiplied and distributed among farmers.